Challenges of small photon field dosimetry are still challenging

Traditionally, beam apertures of dimension 4 × 4 cm^2 to 40 × 40 cm^2 were used for delivering external photon beam treatments to patients by using conventional therapy equipment such as telecobalt machines and standard medical electron linear accelerators with jaw type or conventional multileaf collimators (MLCs; leaf width > 5 mm). However, small (narrow or sub-centimeter) beam apertures are used for delivery of prescribed dose to patients by advanced photon beam radiotherapy techniques (intensity modulated radiotherapy, IMRT; image-guided radiotherapy, IGRT; stereotactic radiosurgery/radiotherapy, SRS/SRT). Both standard and specialized (e.g. Cyber Knife and Tomotherapy) medical electron linear accelerators with high resolution MLCs as well as specialized teleisotope machines (e.g. Gamma Knife) deliver treatments by using small photon fields. The use of small photon fields is almost a pre-requisite for high precision localized dose delivery to delineated target volume, sparing of organs at risk, and escalating the dose to the tumor for improved control of the disease (e.g. prostate). Thus, small-beam apertures are important for fulfilling the clinical goal of radiotherapy. However, such fields have inherent characteristics of charge particle disequilibrium and high-dose gradient, making dosimetric measurements challenging. A small photon field is generally defined as the one having dimensions smaller than the lateral range of the charged particles that contribute to the dose deposited at a point along the central axis of the beam.[1,2] According to this criteria, field sizes of less than 3 × 3 cm^2 are considered to be small for 6 MV photon beam.[3]

The dosimetry of small photon field presents many challenges, which are related to source occlusion, lateral electronic disequilibrium, and the choice of the detector. The first challenge in narrow-beam dosimetry is the definition of the field size. The conventional approach of classifying fields based on the full width at half maximum (FWHM) of their profiles is not necessarily appropriate because of reduction in output on the central axis and the overlapping penumbra.[1] The classification of radiation fields as small actually needs to account for how dose varies with field size, photon beam energy, and absorbing medium. The second challenge is the accurate measurement of standard dosimetric quantities required for patient dose calculation. The accurate measurement of standard dosimetric quantities in such situations strongly depends on the size of the detector with respect to the field dimensions. A relatively large detector sufficiently perturbs the particle fluence in the medium making conversion from measured ionization to dose erroneous if the currently available perturbation correction factors based on cavity theory are used.[2] In addition, photon and electron energy spectra also change as the field size decreases, with the mean energy of the beam increasing with decreasing field size. This has further implications in measurement of reference dose based on existing dosimetry protocols. The third challenge is the difficulty in modeling the beams and calculating patient doses in treatment planning systems. The use of a model designed and optimized for large fields may cause serious inaccuracies in the prediction of patient doses from small fields or segments.[2] Finally, for some specialized delivery equipment that uses small size fields and are used extensively for SRS/SRT (Novalis Tx, Gamma Knife) and IMRT/IGRT (Cyber Knife, Tomotherapy), the reference irradiation geometry specified in the standard dosimetry protocols for beam calibration cannot be realized.

IPEM Report 103[2] suggested including field sizes of less than 40 mm under the category of small photon fields. This definition of small photon field is based on the collimator setting, which can be termed as nominal small photon field sufficient to draw attention while selecting a detector for dosimetry measurements. However, a suitable detector selected for the nominal small photon field may not be suitable for dealing with field sizes far smaller than 40 mm. This is because the rate of reduction in dose rate along the central axis with reducing field size is not linear, and a rapid reduction is observed when the field size becomes far smaller than 40 mm. This problem can partly be solved by further classifying the small photon field as conventional small photon field (CSPF) and very small photon field (VSPF).[3] This classification is expected to further improve the accuracy in measurement of dosimetry parameters (e.g. output factor). However, the question is whether we have a well-tested, easy to use,

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cost-effective dosimeter that can routinely be used by a clinical medical physicist with confidence while dealing with VSPF. This question is yet to be answered and still challenging.

For clinical reference dosimetry (i.e. output measurement) of small photon field, a new dosimetry formalism was proposed to extend the recommendations given in conventional code of practice.[4] However, the measurements of prescribed correction factors of this formalism requires specialized arrangements and sufficient data need to be generated for easy clinical implementation of this formalism. A graphite calorimeter was developed having a sensitive volume of size equivalent to secondary standard ionization chamber in order to provide a more direct way of measuring absorbed dose in IMRT treatment fields.[5] This development is expected to simplify the reference dosimetry of small photon field.

The dosimetry of small photon field is not yet well established unlike the dosimetry of a conventional photon beam. A number of developments (dosimeters, standards, protocols for reference and relative dosimetry, etc.) are required to make it universally acceptable. In the interim period, different types of suitable detectors should be used while measuring the standard dosimetric quantities required for patient dose calculation. This will enhance the confidence in accepting and using the numerical values of required parameters. In the current scenario, it is appropriate to state that the challenges of small photon field dosimetry are still challenging.

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